Ecological Modelling 314 (2015) 90–99

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

Comparing fuels reduction and patch mosaic fire regimes for reducing fire spread potential: A spatial modeling approach

Brean W. Duncan*, Paul A. Schmalzer, David R. Breininger, Eric D. Stolen

NASA Kennedy Space Center Ecological Program, InoMedic Health Applications, Mail Code: IHA-300, Kennedy Space Center, FL 32899, United States

ARTICLE INFO

Article history:
Received 27 January 2015
Received in revised form 14 July 2015
Accepted 16 July 2015
Available online 12 August 2015

Keywords:
Fire modeling
Fire management
Fire hazard
FARSITE
Patch mosaic burning
Fuels reduction

ABSTRACT

Reduction of fire hazard is becoming increasingly important in managed landscapes globally. Fuels reduction prescribed burn treatments are the most common form of reducing fire hazard on landscapes around the world but often result in homogenized fuel age structures and habitats. Alternatively, the size of unplanned fires, and hence fire hazard, can be reduced by controlling the size and patterning of fuels treatments in a patch mosaic arrangement on landscapes. Patch mosaic burning is being implemented globally as a means to increase heterogeneity to mimic natural fire regime results. Funding for prescribed fire programs is often justified primarily on hazardous fuels reduction with secondary consideration given for ecological effectiveness, which can be increased by particular fire mosaic patterns in some systems. The question we address is: Which of two prescribed fire treatment regimes, fuels reduction or patch mosaic burning, reduces fire hazard most effectively? We address the question using computer simulation modeling on synthetic landscapes representing both fire regime treatments. Treatment scale was important. Among fuel reduction treatments, large blocks burned less area than small blocks. For the mosaic treatments, small blocks reduced fire size the most (out of all treatments) and had the least variance in area burned. It is possible to reduce fire hazard and to provide heterogeneous age fuels structure on the landscape, simultaneously benefiting humans and many native fire-dependent species requiring mosaic habitat patterns.

1. Introduction

There is a paradigm shift occurring in global fire management from fuels reduction to mosaic fire regimes, often referred to as patch mosaic burning (Haslem et al., 2011; Parr and Brockett, 1999; van Wilgen, 2009; Weir et al., 2000). Fuels reduction burning prescribes fire to consume fuels in designated management units that have not burned for some set duration of time. This process reduces fuel continuity on the landscape, minimizing potential fire spread, thus reducing fire hazard. Patch mosaic burning is a strategy to create a fine-grained mixture of different post-fire age patches randomly spread across the landscape. The focus of patch mosaic burning is to create heterogeneity on the landscape while also reducing fuel loads.

Reducing hazardous fuel levels has been a leading justification for conducting prescribed burns in many regions of the world (Adrian, 2003; McCaw, 2013; Ryan et al., 2013; Sow et al., 2013; USDI, 1995; Williams, 2013). Here we define fire hazard as a fuel complex by volume, type condition, arrangement, and location that determines the ease of ignition and resistance to control (NWCG, 2012). Fire hazard expresses the potential fire behavior for a fuel type, regardless of the fuel type's weather-influenced fuel moisture content (Hardy, 2005). Decades of fire suppression have resulted in a build-up of fuels, necessitating reduction of hazardous fuel levels. There are many benefits to fuels reduction burning, but important ecological aspects are often overlooked in an effort to burn out fuels uniformly inside of management units (Breininger et al., 2014a, 2009; Fuhlendorf et al., 2006).

With increased interest in mimicking natural fire regimes through prescribed fire, there has been improved knowledge of historic fire regimes (Beckage et al., 2005; Bergeron et al., 2002; Duncan et al., 2010, 2011; Perera and Cui, 2010). With this knowledge has come awareness of high rates of inherent variability and heterogeneity (Bergeron et al., 2002; Bragg, 2002; Duncan et al., 2011; McEwan et al., 2007; Rollins et al., 2001; Stambaugh et al., 2011) supporting the concept of pyrodiversity (varied fire size, patterns, severities, intervals, and to lesser extent seasons) (Davies et al., 2012; Faivre et al., 2011; Parr and Andersen, 2006). Natural fire regimes in different ecosystems created different scales of heterogeneity, and species have adapted to these

* Corresponding author. Tel.: +1 321 861 6292; fax: +1 321 867 3694.
E-mail address: brean.w.duncan@nasa.gov (B.W. Duncan).

http://dx.doi.org/10.1016/j.ecolmodel.2015.07.013
0304-3800/

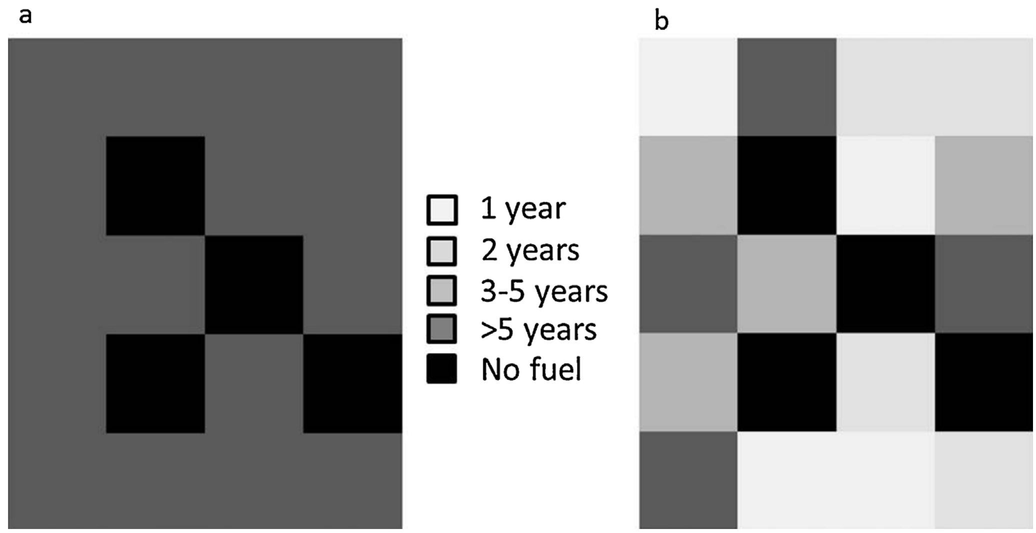

Fig. 1. Examples of single-age fuel mosaic (a) and multiple-age fuel mosaic (b) fire regime configurations. The single-age fuel mosaic configuration contains 80% mature fuels and 20% non-fuels while the multiple-age fuel mosaic configuration has the same 20% non-fuels with four different age fuels each comprising 20% of landscape. This example of the two regime fuel configurations has the 8 km by 10 km landscape divided up into 2 km (400 ha) cells.

particular allocations of resources, making it important to understand the optimum arrangement of heterogeneity for co-habiting fire dependent species (Bradstock et al., 2005). The specific formation of spatial and temporal heterogeneity is particularly important in maintaining biodiversity and is thus at the heart of the "pyrodiversity begets biodiversity" paradigm (Taylor et al., 2012) with spatial age pattern mosaics being documented in many historic fire regimes worldwide (Duncan et al., 2011; Faivre et al., 2011; Fernandez-Manso et al., 2009; Minnich, 1983; Wimberly, 2002).

While reducing fuels remains the highest priority among benefits of prescribed fire management, it is fair to ask: whether fuels reduction or patch mosaic burning regime reduce fire spread and fire hazard most effectively? There are global examples of native and local people burning seasonal mosaics to reduce catastrophic fire potential among other motives (Laris, 2002; Lewis, 1989; Lewis and Ferguson, 1988). Prescribed burn treatment levels, unit size, and spatial patterning have been found to reduce potential unplanned fire extents (Fernandes and Botelho, 2003; Finney, 2001; King et al., 2008, 2006; Loehle, 2004; Schmidt et al., 2008). Many of these studies used simulation modeling to explore the relationship between fuels management and fire behavior with few empirical studies having the ability to quantify fuel treatment effect on mitigating unplanned fires (Boer et al., 2009).

Our objectives were to compare directly fuels reduction and mosaic fire regimes for reducing fire spread potential. By reducing fire spread potential, fire hazard is also reduced. A secondary objective was to vary the arrangement and scale of fuel to determine their influence on fire spread under both fire regimes. A third objective was to explore the ecological contexts, ramifications, and management implications of each regime. We used a fire event model on synthetic landscapes, holding all variables constant with exception of scale and distribution of fuel age mosaic, isolating the effect of mosaic scale and arrangement on fire size. By conducting the study in this manner, we were able to compare relative results of each treatment directly. We tested random mosaic patterns excluding regular patterns because maximizing heterogeneity in prescribed fire management is increasingly important. Both regimes reduce fuels and both produce age mosaics; for clarity and consistency we refer to the fuel reduction regime as the single-age fuel mosaic (SAFM) and the patch mosaic regime as the multiple-age fuel mosaic (MAFM) for the duration of this manuscript. This research is globally relevant for land owners, land managers, conservationists, and fire scientists because it extends and builds on previous research studying the characteristics of prescribed burn treatments and implications for endangered species management.

2. Methods

2.1. Conceptual background

We modeled the SAFM regime using landscapes with 80% even-age mature fuels and 20% non-fuels (Fig. 1a). The non-fuels were dispersed randomly on the landscape and represented areas where fuels were recently treated by complete burn out in those management units. Mature fuels were used because the rotation of prescribed fire in the SAFM regime is often sufficiently long to allow fuels to mature between fires. We simulated the MAFM fire regime using the same arrangement of 20% non-fuels; however, four fire behavior fuel types representing different age fuels were distributed randomly on the landscape so that each of the five types comprised 20% of the landscape (Fig. 1b). This created a MAFM on the landscape of different fuel types. For this manuscript, we define the MAFM as being created by frequent, small fires randomly distributed across the landscape leaving a heterogeneous patchwork of different age classes. It is important to note that the legacy of the MAFM fire regime is a cycling persistence of this heterogeneous patchwork of different age fuels on the landscape and in this study the starting point for our MAFM fire treatments.

2.2. FARSITE simulations

We used the Fire Area Simulator model (FARSITE) version 4.0 (Finney, 2004) for all spatial fire modeling with ASCII grid format input directly from ArcGIS 10.0 software (Environmental Systems Research Institute, 2013). We conducted simulations for five days on synthetic landscapes with empirical fuel and meteorological inputs from Kennedy Space Center (KSC)/Merritt Island National Wildlife Refuge (MINWR) in east central Florida. Meteorological (Table 1) and fuels moisture inputs (used by FARSITE to calculate fire behavior) were from Duncan and Schmalzer (2004) and followed the average summer scenario (typical peak lightning season conditions) (Duncan et al., 2010). Initial fuel moisture inputs were the same for all fire behavior fuel models with 1-h values of 10%,